International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 4, Issue 2, Apr 2014, 127-138

COMPARATIVE STUDY OF PROPERTIES OF SELF COMPACTING CONCRETE WITH GROUND GRANULATED BLAST FURNACE SLAG AND FLY ASH AS ADMIXTURES

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ABSTRACT

The Self Compacting Concrete is one; whose ingredients are proportioned in such a manner that it can be placed and compacted into any shape of the formwork, purely means of its self weight by eliminating any type of external compacting effort. SCC is the most revolutionary development in concrete construction for several decades. The utilization of SCC is growing rapidly nowadays. To make the SCC more durable and economical it is general trend to add the treated and untreated industrial by products, raw materials, domestic wastes etc. in concrete. This not only results in the reuse of the waste materials but also create a cleaner and greener environment. Experimental study is carried out and the behavior of SCC with Ground Granulated Blast Furnace Slag & Fly Ash is investigated. The effect of use of above mineral admixture fines on fresh properties of SCC is studied. A suitable & appropriate chemical admixture i.e. super plasticizer is used.

KEYWORDS: Self Compacting Concrete, GGBFS, Modified Nan-Su Method, Flow Ability, Workability, Pass Ability, Fly Ash

INTRODUCTION

With growing population, industrialization and urbanization, there is corresponding growth in the demand for infrastructure. SCC has occupied a unique position among modern construction materials. It gives considerable freedom to the architect to mould structural elements to any shape. Almost all concretes rely critically on being fully compacted. Insufficient compaction dramatically lowers ultimate performance of concrete in spite of good mix design. Concrete is the most widely consumed material in the world, after water. Placing the fresh concrete requires skilled operatives using slow, heavy, noisy, expensive, energy-consuming and often dangerous mechanical vibration to ensure adequate compaction to obtain the full strength and durability of the hardened concrete. Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.

The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete. Popularity of using self-compacting concrete (SCC) in concrete construction is increased in many countries, since SCC is effectively applied for improving durability of structures while reducing the need of skilled workers at the construction site. Self-compacting concrete (SCC) offers various advantages in the construction process due to its improved quality, and productivity. SCC has higher powder content and a lower coarse aggregate volume ratio as compared to normally vibrated concrete (NVC) in order to ensure SCC's filling ability, passing ability and segregation resistance. Only cement is used in SCC, it is become high costly, susceptible to be attacked and produces much thermal

crack. It is therefore necessary to replace some of the cement by additions, to achieve an economical and durable concrete. Nowadays, the ecological trend aims at limiting the use of natural raw materials in the field of building materials and hence there is an increased interest in the use of alternative materials (waste) from various industrial activities, which presents significant advantages in economic, energetic and environmental terms. This study aims to focus on the possibility of using waste material in a preparation of innovative concrete. Two kind of waste were identified: Fly Ash and Ground Granulated Blast Furnace Slag.

LITERATURE REVIEW

Pazhani.K., Jeyaraj.R. Investigated to assess the durability parameters of high performance concrete with the industrial wastes. Durability parameters such as water absorption and chloride penetration are to be studied.

Kamran Muzaffar Khan, Usman Ghani. Investigated the relevant properties of cement Effect of replacement was seen on workability, compressive strength, tensile strength, modulus of rupture, equivalent cube strength by casting mixes of different ratios; 1:2:4, 1:1.5:3, 1:1.25:2.50, 1:1:2. W/C ratio for first two mixes was kept as 0.65 and for rest two mixes as 0.45.After cost comparison of GGBS and Ordinary Portland Cement it is concluded that p rice of G GBS is 25% to 50% less than that of Ordinary Portland Cement. This aspect of GGBS makes it economical.

C. Yalçınkaya, H. Yazıcı Investigated the Mechanical and fresh state performance of steel fibred self-compacting concrete (SFRSCC) with high volume ground granulated blast furnace slag (GGBFS). GGBFS was replaced with cement in high volume (50%, by weight). Test results showed that steel fibres affected fresh state performance adversely but enhanced mechanical properties importantly. Steel fibres increased the fracture energy and flexural strength. High volume GGBFS replacement also increased the flexural and compressive strengths.

Vilas V. Kirjinni & Shrishail B. Anadinn. They emphasized on the mixture proportion which is one of the important parameter in the self compacting concrete. They have used modified Nan-su method and obtained mix design in normal grades with different mineral admixtures & the compressive strength and flow properties of SCC were also studied.

Kannan V. Ganeshan K It is investigated that the use of Metakaolin and Fly Ash Provides a positive effect on mechanical and transport properties of SCC. It also shows that the sample incorporating the ternary blend of cement with 15% Metakaolin and 15 % Fly Ash proved better compressive strength than that of normal SCC

Vilas V. Karjinni, Shrishail B.Anadinni, et al. Presented a comparative evaluations of fresh and hardened properties of SCC using different mineral admixture with Nan-su and Modified Nan-su mix design method.The modified Nan-su method was used for mix design of SCC and also investigated the compatibility of GGBS in SCC along with chemical admixture such as super plasticizer and to study the durability aspect of SCC.

RESEARCH SIGNIFICANCE

The advancement in concrete technology to overcome the field problems is use of Self-compacting concrete (SCC). Self-compacting concrete (SCC) has recently been one of the most important developments in the concrete technology. For a newly developing material like Self compacting concrete, studies on durability is of paramount importance for instilling confidence among the engineers and builders. The literature indicates that some studies are available on the SCC with different mineral admixture as powder content (filler) but comprehensive studies are not available on fresh properties of self compacting concrete with different percentages of GGBFS & FA. Hence, considering

the gap in the existing literature, an attempt has been made to study the effect of mineral admixture (GGBFS & FA) on the fresh properties of self compacting concrete.

REQUIREMENTS FOR CONSTITUENT MATERIALS

Materials

Cement

Selection of the type of cement will depend on the overall requirements for the concrete, such as strength, durability, etc. In this experimental study, Ordinary Portland cement 53 grade conforming to IS: 8112-1989.

Table 1: Properties of Cement

Physical Property	Results
Fineness (retained on 90-µm) sieve)	8%
Normal Consistency	28%
Vicat initial setting time(minutes)	75
Vicat final setting time (minutes)	215
Specific gravity	3.15
Compressive strength at 7-days	20.6 MPa
Compressive strength at 28-days	51.2 MPa

Coarse and Fine Aggregates

All types of aggregates are suitable. The normal adopted size is ranged 10-12mm and limited to 20mm. Consistency of grading is of vital importance. Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 2 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 2 was used as coarse aggregate.

Table 2: Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.66	2.95
Fineness Modulus	3.1	7.69
Surface Texture	Smooth	--
Particle Shape	Rounded	Angular
Crushing Value	---	17.40
Impact Value	---	12.50

Ground Granulated Blast Furnace Slag (GGBFS),

Ground Granulated Blast-Furnace Slag powder is a fine white dust. It is made from Blast-Furnace Slag - a co-product of iron and steel. For this work GGBFS was obtained from Quality Polytech, Manglore - Karnataka.

Table 3: Properties of GGBFS

Characteristics	Test Results
Fineness (m^2/kg)	33
Specific Gravity (%)	2.24
Magnesia content (%)	8.34
Sulphide sulphur (%)	0.50
Sulphite content (%)	0.52
Loss on ignition (%)	0.16
Manganese content (%)	0.09
Chloride content (%)	0.010
Glass content (%)	93

Fly Ash

Fly ash is a very grey powder obtained after burning a coal. The combustion of powder coal in thermal power plant produces fly ash. For this work fly ash was obtained from thermal power station Paras, Akola (MS) India.

Table 4: Physical Properties of Fly Ash

Sr. No.	Physical Properties	Test Results
1.	Colour	Grey (Blackish)
2.	Specific Gravity	2.13
3.	Fineness	18

Table 5: Chemical Properties of Fly Ash

Sr. No.	Constituents	Percent by Weight
1.	Loss on ignition	4.17
2.	Silica ($SiO2$)	58.55
3.	Iron Oxide ($Fe2\ O3$)	3.44
4.	Alumina ($Al2\ O3$)	28.20
5.	Calcium Oxide (CaO)	2.23
6.	Magnesium Oxide (MgO)	0.32
7.	Total Sulphur ($SO3$)	0.07

Admixture (Super Plasticizer)

The most important admixtures are the Super plasticizers (high range water reducers), used with a water reduction greater than 20%.

Table 6: Physical Properties of Super Plasticizer

Physical Properties	Results Results
Chloride Content	Nill
Specific Gravity	1.25
Colour	Greenish

Super plasticizers are essential components of SCC to provide necessary workability. The new generation poly carboxylated ether (PCE) super plasticizer is particularly used for SCC. A product of FOSROC manufacturer, of brand name CONPLAST SP 430 G8 was used as a super plasticizer with a density of 1.2 kg/lit. It was used to provide necessary workability, which complies with IS 9103-1999 & BS- 5075, Part – 3, It also confirms to ASTM - C – 494.

Mixing Water

Water Quality must be established on the same line as that for using reinforced concrete or prestressed concrete.

MIX PROPORTIONING

The mix proportion was done based on the Modified Nan-Su method. The mix design was carried out for M30 normal grade of self compacting concrete with GGBFS & FA as partial replacement of cement with a fraction of 10%, 20% & 30%.

Table 7: Quantities of Materials for 1m^{3}of SCC Mixes

Mix	Mix-1 (kg/m^3)	Mix-2 (kg/m^3)	Mix-3 (kg/m^3)
Cement	343.8	305.6	267.2
GGBFS (Filler)	301	301	301
GGBFS as Cement Replacement	38.2	76.4	114.8

Table 7: Contd.,

Total Powder Content	677	677	677
Fine Aggregate	710	710	710
Coarse Aggregate	612	612	612
W/P (0.38)	260	260	260
SP (0.8 %)	4.098	4.098	4.098

Mix-1:- 10% Replacement of Cement with GGBFS
Mix-2:- 20% Replacement of Cement with GGBFS
Mix-3:- 30% Replacement of Cement with GGBFS

Table 8: Quantities of Materials for 1m^{3}of SCC Mixes

Mix	Mix-1 (kg/m^3)	Mix-2 (kg/m^3)	Mix-3 (kg/m^3)
Cement	343.8	305.6	267.2
FA (Filler)	260	260	260
FA as Cement Replacement	38.2	76.4	114.8
Total Powder Content	642	642	642
Fine Aggregate	710	710	710
Coarse Aggregate	612	612	612
W/P (0.36)	232	232	232
SP (0.8 %)	5.136	5.136	5.136

Mix-1:- 10% Replacement of Cement with FA
Mix-2:- 20% Replacement of Cement with F.
Mix-3:- 30% Replacement of Cement with FA

PROPERTIES OF SELF COMPACTING CONCRETE

Properties of Fresh SCC

A concrete mix is called Self Compacting Concrete if it fulfills the requirement of filling ability, passing ability and resistance to segregation.

Filling Ability: The property of SCC to fill all corners of a formwork under its own weight is known as filling ability. (Measured by slump test)

Passing Ability: The property of SCC to flow through reinforcing bars without segregation or blocking. (Measured by L-box test)

Resistance to Segregation: The property of SCC to flow without segregation of the aggregates. (Measured by V-funnel test)

Several test methods are available to evaluate these main characteristic of SCC, The tests have not been standardized by national or international organizations. The more common tests used for evaluating the compacting characteristics of fresh SCC in accordance with the draft standards of the Japan society of civil engineers are described below.

Test Method for Fresh SCC

The main characteristics of SCC are the properties in the fresh state. SCC mix design is focused on the ability to flow under its own weight without vibration, the ability to flow through heavily congested reinforcement under its own weight, and the ability to obtain homogeneity without segregation of aggregates.

Several test methods are available to evaluate these main characteristics of SCC. The tests have not been

standardized by national or international organizations. The more common tests used for evaluating the compacting characteristics of fresh SCC are described below.

- The Slump Flow Test
- L Box-Type Tests
- V-Funnel Test

Table gives the recommended values for different tests given by different researches for mix to be characterized as SCC.

Table 9: Recommended Limits for Different Properties (As per EFNARC)

Sr.No.	Tests	Properties	Range
1.	The Slump Flow Test	Filling ability	650-800 mm
2.	V-Funnel Test	Viscosity	6-12 sec.
3.	L-Box H_2/H_1	Passing ability	0.8 - 1.0

Figure 1: Slump Cone

Slump Flow Test

It is the most commonly used test and gives a good assessment of filling ability. The slump cone is held down firmly. The cone is then filled with concrete. No tamping is done. Any surplus concrete is removed from around the base of the concrete.

Figure 2: Slump Flow Test

After this, the cone is raised vertically and the concrete is allowed to flow out freely. The diameter of the Concrete in two perpendicular directions is measured. The average of the two measured diameters is calculated. This is the slump flow in mm, The higher the slump flow value, the greater its ability to fill formwork under its own weight. The range is from 600 mm to 800 mm.

L Box Test Method

Figure 3: L Box Test Apparatus

It assesses filling and passing ability of SCC. The vertical section is filled with concrete, and then gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the heights 'HI' and 'H2' are measured. Closer to unit value of ratio 'H2/H1' indicates better flow of concrete.

V- Funnel and V- Funnel at T5 mm

Figure 4: Funnel and V- Funnel Test

The test measures flow ability and segregation resistance of concrete. The test assembly is set firmly on the ground and the inside surfaces are moistened. The trap door is closed and a bucket is placed underneath. Then the apparatus is completely filled with concrete without compacting. After filling the concrete, the trap door is opened and the time for the discharge is recorded. This V-funnel determines the filling ability of concrete.

This is taken to be when light is seen from above through the funnel. To measure the flow time at T 5minutes, the trap door is closed and V-funnel is refilled immediately. The trap door is opened after 5 Minutes and the time for the discharge is recorded. This is the flow time at T 5 minutes. Shorter flow time indicates greater flow ability. V- Funnel at T5 mm indicates the resistance to segregation. It should be 0-3 sec. if concrete segregates, time increases.

RESULTS

Fresh Properties SCC

GGBFS was used to replace the cement content by three various percentages (10, 20 and 30%). The partial replacement with GGBFS was carried out for M30 grades of concrete. To fulfill the requirement of SCC in fresh state and evaluate flow characteristic using slump cone, V-funnel, & L-box tests and to fix dosage of super plasticizer (HRWRA) as per EFNARC guidelines and fix the dosage of water /powder ratio was needed. The test results are presented in the table 10, 11.

Table 10: Fresh Properties SCC with GGBFS

Test	Mix-1	Mix-2	Mix-3
Slump Flow Test	710 mm	670 mm	650 mm
V-Funnel Test	6.60 Sec	6.76 Sec	6.47 Sec
L-Box	0.89	0.88	0.85

Table 11: Fresh Properties SCC with Fly Ash

Test	Mix-1	Mix-2	Mix-3
Slump Flow Test	700 mm	690 mm	670 mm
V-Funnel Test	6.1 Sec	6.6 Sec	6.9 Sec
L-Box	0.922	0.889	0.850

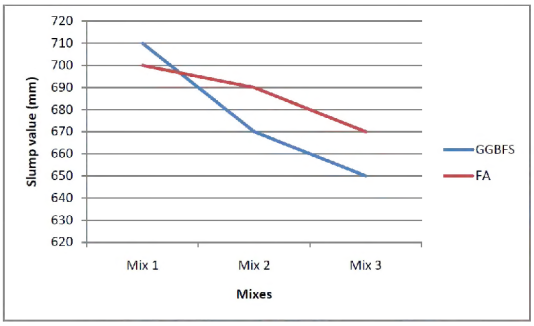

Figure 5: Slump Flow Value with GGBFS & FA

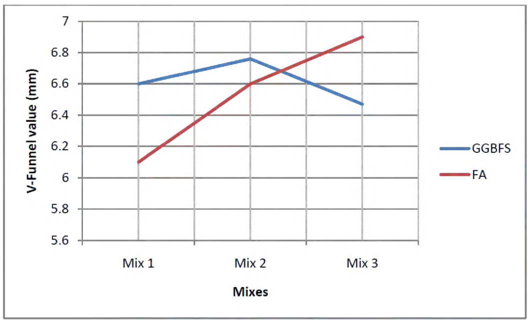

Figure 6: V-Funnel Value with GGBFS & FA

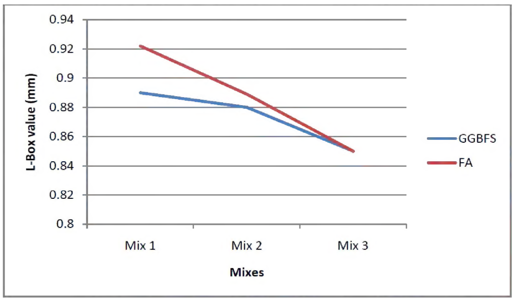

Figure 7: L-Box Value With GGBFS & FA

Hardened Properties Ground Granulated Blast Furnace Slag (GGBFS)

Hardened Properties-: (7 Days)

Table 12

Types	Mix 1		Mix 2		Mix 3	
Compressive Strength	24 Mpa	25.33 Mpa	23.5 Mpa	24.83 Mpa	19 Mpa	20.33 Mpa
	26 Mpa		25 Mpa		21 Mpa	
	26 Mpa		26 Mpa		21 Mpa	
Flexural Strength	4.59 Mpa	4.49 Mpa	4.32 Mpa	4.12 Mpa	3.78 Mpa	3.92 Mpa
	4.39 Mpa		3.92 Mpa		4.05 Mpa	
Split Tensile Strength	3.26 Mpa		2.83 Mpa		2.55 Mpa	

Hardened Properties-: (28 Days)

Table 13

Types	Mix 1		Mix 2		Mix 3	
Compressive Strength	37 Mpa	39.33 Mpa	35.5 Mpa	37 Mpa	28.5 Mpa	30.5 Mpa
	39 Mpa		37.5 Mpa		32 Mpa	
	42 Mpa		38 Mpa		31 Mpa	
Flexural Strength	6.90 Mpa	6.75 Mpa	6.49 Mpa	6.19 Mpa	5.68 Mpa	5.88 Mpa
	6.60 Mpa		5.89 Mpa		6.09 Mpa	
Split Tensile Strength	4.9 Mpa		4.25 Mpa		3.83 Mpa	

Hardened Properties-: (91 Days)

Table 14

Types	Mix 1		Mix 2		Mix 3	
Compressive Strength	44 Mpa	44 Mpa	42 Mpa	42 Mpa	38 Mpa	38 Mpa
	45 Mpa		42 Mpa		39 Mpa	
	43 Mpa		40 Mpa		38 Mpa	
Flexural Strength	9.78 Mpa	9.66 Mpa	9.24 Mpa	9.27 Mpa	9.21 Mpa	9.168 Mpa
	9.54 Mpa		9.30 Mpa		9.12 Mpa	
Split Tensile Strength	4.95 Mpa		4.81 Mpa		4.23 Mpa	

Hardened Properties Fly Ash

Hardened Properties-: (7 Days)

Table 15

Types	Mix 1		Mix 2		Mix 3	
Compressive Strength	24.5 Mpa	24.33 Mpa	22 Mpa	22.83 Mpa	22 Mpa	20.17 Mpa
	24 Mpa		24 Mpa		20 Mpa	
	24.5 Mpa		22.5 Mpa		18.5 Mpa	
Flexural Strength	4.59 Mpa	4.49Mpa	3.51 Mpa	3.51 Mpa	3.24 Mpa	3.24 Mpa
	4.39 Mpa		3.51 Mpa		3.24 Mpa	
Split Tensile Strength	2.62 Mpa		2.05 Mpa		1.91 Mpa	

Hardened Properties-: (28 Days)

Table 16

Types	Mix 1		Mix 2		Mix 3	
Compressive Strength	32 Mpa	30.33 Mpa	32 Mpa	30Mpa	30 Mpa	27.33 Mpa
	30 Mpa		28 Mpa		27 Mpa	
	29 Mpa		30 Mpa		25 Mpa	
Flexural Strength	5.4 Mpa	5.5 Mpa	4.32 Mpa	4.32 Mpa	3.92 Mpa	3.79 Mpa
	5.67 Mpa		4.32 Mpa		3.62 Mpa	
Split Tensile Strength	3.82 Mpa		3.54 Mpa		3.11 Mpa	

Hardened Properties-:(91 Days)

Table 17

Types	Mix 1		Mix 2		Mix 3	
Compressive Strength	35 Mpa	35 Mpa	33 Mpa	33 Mpa	31 Mpa	29.66 Mpa
	34 Mpa		33 Mpa		28 Mpa	
	35 Mpa		32 Mpa		30 Mpa	
Flexural Strength	7.44 Mpa	6.87 Mpa	7.5 Mpa	7.83 Mpa	6.72 Mpa	6.24 Mpa
	6.3 Mpa		8.16 Mpa		5.76 Mpa	
Split Tensile Strength	4.529 Mpa		4.317 Mpa		3.963 Mpa	

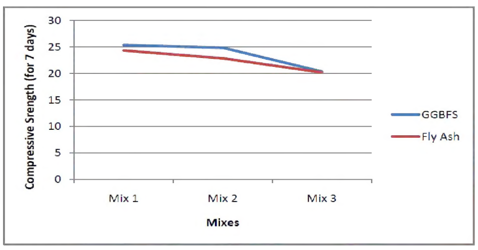

Figure 8: Compressive Strength Value with GGBFS & FA (7 Days)

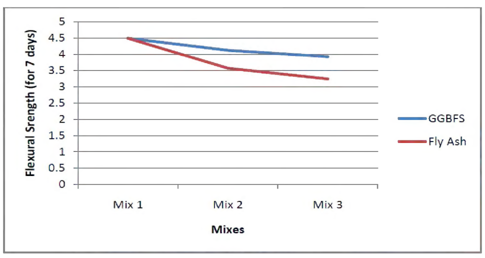

Figure 9: Flexural Strength Value with GGBFS & FA (7 Days)

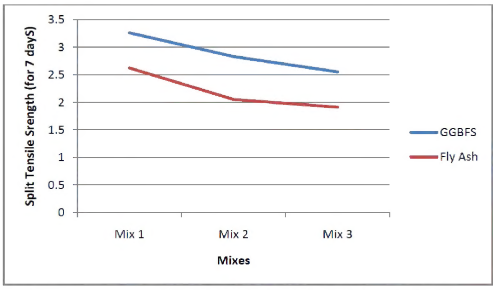

Figure 10: Split Strength Value with GGBFS & FA (7 Days)

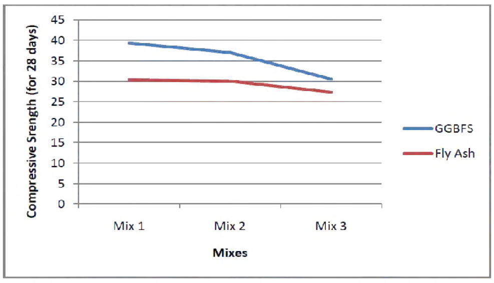

Figure 11: Compressive Strength Value with GGBFS & FA (28 Days)

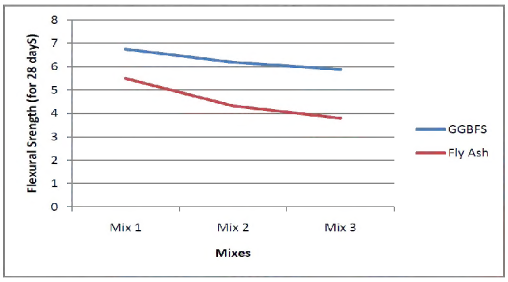

Figure 12: Flexural Strength Value with GGBFS & FA (28 Days)

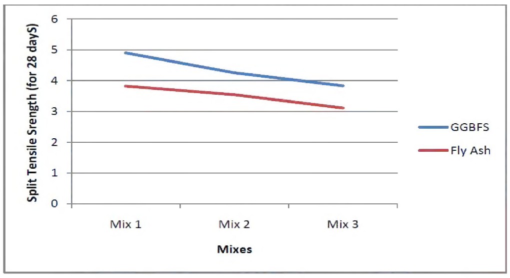

Figure 13: Split Strength Value with GGBFS & FA (28 Days)

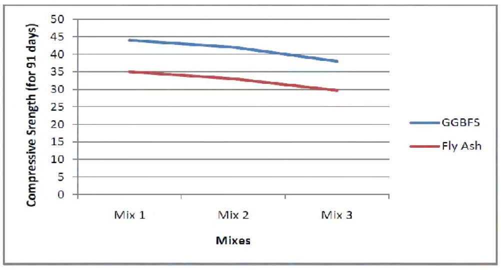

Figure 14: Compressive Strength Value with GGBFS & FA (91 Days)

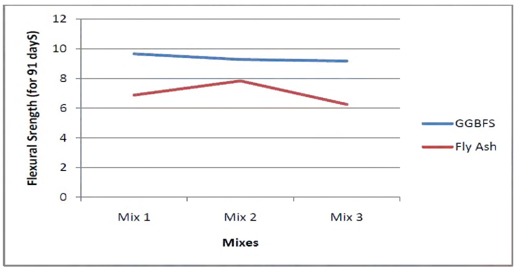

Figure 15: Flexural Strength Value with GGBFS & FA (91 Days)

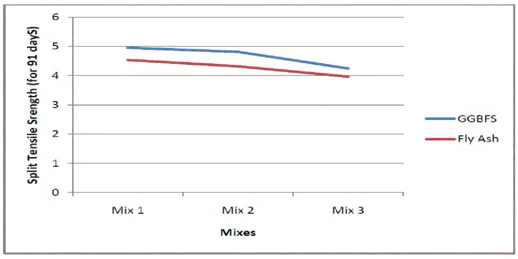

Figure 16: Split Strength Value with GGBFS & FA (91 Days)

CONCLUSIONS

- It has been reported that economically competitive SCC can be produced by replacing up to 50% of OPC with GGBFS & FA Ash.
- As long as the correct proportions are used when replacing Ordinary Portland Cement with GGBFS & Fly Ash the durability of the structure will be enhanced, leading to a longer life for the concrete.
- The addition of 10 %, GGBFS and Fly Ash in SCC mixes increases the self compactability characteristic like filling ability, passing ability, flowing ability and segregation resistance.

- The compressive strength, flexural strength & split tensile strength of SCC increases for 7 days, 28 days, and 91 days of curing, with replacement levels of 10%, 20%, 30 % of cement by GGBFS and Fly Ash.
- But it can also be seen that compressive strength, flexural strength & split tensile strength is maximum for 10% replacement as compared to 20% and 30 %.

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